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Production and Utilization of White Potato Starch[1]

About seven percent of the annual American potato crop, or 25,000,000 bushels, is converted into potato starch by 21 factories in Maine and six in Idaho, with a combined capacity of annually producing about 150,000,000 pounds of starch, used principally in sizing textiles but also in the manufacture of paper, food products and adhesives.

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Introduction

The potato (*Solanum tuberosum*) is the most important vegetable grown in the United States from the standpoints of both tonnage produced and dollar value of the crop. About 75 percent of our potatoes are used for food in the fresh and processed forms. Approximately ten percent of the annual yield is required for seed for the succeeding crop. The remaining 15 percent is made up of sub-standard potatoes that are unsuitable for the tablestock market because they are too small, too large, misshapen or damaged. These culls are available for feed and industrial uses. In addition to the culls, surplus potatoes are utilized in non-food outlets during large crop years.

Livestock feeding is the largest single outlet for cull and surplus potatoes, consuming one-half to two-thirds of the total utilized in non-food channels. Most of the remaining cull potatoes are used to produce starch.

Potato and wheat were the leading domestic starches early in the nineteenth century. The first potato starch plant in the United States was established in 1831 at Antrim, New Hampshire (2). By about 1880 there were more than 150 potato starch factories operating in Maine, New Hampshire, Vermont, Michigan, Wisconsin, Ohio and Minnesota (4). The industry, from its early history up to the present, has been made up of numerous small plants instead of several large factories, as we find in cornstarch manufacture. In Maine and other States, special varieties of potatoes were grown for starch manufacture. These varieties were not of outstanding culinary quality but contained a relatively large amount of starch. In the Netherlands and Germany different types of potatoes are still grown for tablestock and for industrial uses.

Late in the nineteenth century potato starch lost its strong position in the general field to cornstarch, which could be sold at a lower price. Potato starch then entered the category of specialty starches.

Corn has several economic advantages over potatoes as a raw material for starch manufacture in the United States. Potatoes will equal or exceed corn in yield of starch per acre, but corn can be produced cheaper because it is better adapted to mechanized methods of farm-

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ing. Corn dries out to 12 to 15 percent moisture content in the field. In this condition it can be shelled, easily transported and stored before processing. Potatoes are about four-fifths water, which adds materially to the bulk and weight in transportation. While potatoes are sufficiently perishable to require special methods of handling, corn is easily stored in elevators from which large factories can draw their raw material throughout the year. Potato starch factories usually operate only about eight months of the year, from October through May. The corn wet milling industry has valuable byproducts, such as oil and gluten feed, which aid in making the industry profitable. The potato starch industry, on the contrary, has no byproduct except the extracted pulp which a few manufacturers recover and sell as feed.

By 1900 the number of potato starch factories had decreased to 63 (2). A decided trend developed toward concentrating the potato starch industry in Aroostook County, Maine, where 45 of the nation's plants were located. Northern Maine became a center for production of tablestock and seed potatoes, with the starch industry providing an outlet for the culls. In 1920 there were about 20 factories in Maine with a combined daily capacity of somewhat less than 75 tons of starch. Although the total productive capacity of Maine's starch industry has increased markedly since that time, owing to the construction of new plants and modernization of existing facilities, the number of plants has remained nearly the same.

The history of American potato starch thus consists of three phases:

1. The period from about 1850 to about 1900, in which it was a leading all-purpose starch.

2. The period from about 1900 to late in the 1930's, when it was a specialty starch greatly overshadowed by corn and tapioca starches in the general field. During this interval much of the high quality potato starch used by American industry was of necessity imported.

3. The recent period in which such an upsurge occurred that the annual production figure was tripled in about 15 years. A revival in the general usage of this starch has made it competitive with cornstarch, to a certain extent, in several applications. However, it still must be kept in mind that approximately ten times as much cornstarch as potato starch is used.

Statistics of Production

At present there are 21 potato starch plants in Maine, having a total capacity for producing about 225 tons of starch a day, or 90 million pounds in a 200-day operating season.

Potato starch production was inaugurated in Idaho late in 1941 with the establishment of plants at Blackfoot and Twin Falls (1). In 1942 a third plant was built at St. Anthony. The fourth plant for the State was established at Menan in 1944 but was later moved to Idaho Falls. Developments in 1948 included the construction of an additional plant at Idaho Falls, the rebuilding of the Twin Falls plant and conversion of a glucose sirup plant at Jerome to starch manufacture. The new Twin Falls plant has the largest capacity of any potato starch factory in the United States. Two-thirds as much starch can be produced in the six Idaho plants as in all of Maine's factories. Thus the entire American industry can turn out about 150 million pounds of starch annually, as it did during the 1950–51 season.

Method of Production

Although disadvantages were pointed out in the storing and handling of potatoes relative to corn, potatoes are definitely easier to process for starch recovery. In the wet processing of corn, the grain must be " steeped ", *i.e.*, soaked for about 48 hours in warm water acidified with sulfur dioxide. Steeping is necessary primarily to soften the kernel so that the various constituents may be separated. Corn must be passed through a special mill to remove the germ of the kernel. The degerminated corn is then passed through buhr mills to disintegrate the tissue and permit separation of the fiber from the starch and gluten.

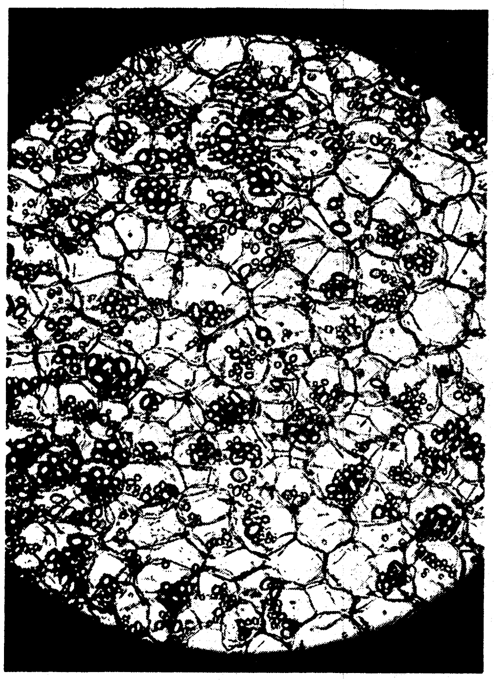

FIG. 1. Section 120 μ thick sliced from the pithy area of raw potato tuber. Magnification, 52 ×.

Potatoes are milled directly after leaving the washer. Either a rasp or a hammer mill is used to disintegrate the potato cells and liberate the starch. The skin and fiber are then separated from the starch by screening. Final purification is similar in both corn and potato starch manufacture. Removal of the water solubles is effected by washing, and the remaining insoluble impurities are separated from the starch by means of specific gravity difference.

A photomicrograph of potato tissue is shown in Fig. 1. The cross section is from a low-starch potato sliced from the center of the tuber, where the starch content is quite low. In this particular section the tissue contains only perhaps five percent starch. However, for the purpose of illustrating how potato cells are grouped together and the manner in which starch granules are packed in the cells, it is preferable to examine a section containing relatively little starch. The walls of potato cells fit closely to one another with only occasional air spaces, in a pattern similar to a honeycomb cross section. The several more tightly packed cells shown in the illustration are typical of potatoes used in starch manufacture.

A typical Maine factory produces about ten tons of starch a day while consuming 80 to 90 tons of potatoes. The average composition of potatoes processed in Maine factories is estimated as follows:

TABLE I.

AVERAGE COMPOSITION OF POTATOES PROCESSED IN MAINE STARCH FACTORIES

Substance	% present
Starch	13
Protein (NX6.25)	2
Cellulosic material	1.5
Sugars	0.5
Mineral (ash)	1
Miscellaneous minor constituents (total)	1
Water	81

Potatoes received by the Idaho starch plants contain perhaps 15–16 percent starch.

The process used in one of the modern plants is illustrated in Fig. 2 and outlined in the following description [3]. The

[3] For a more complete discussion and operating data on potato starch processing, see Howerton, W. W., and Treadway, R. H., Manufacture of white potato starch, Ind. and Eng. Chem., 40: 1402–1407 (1948).

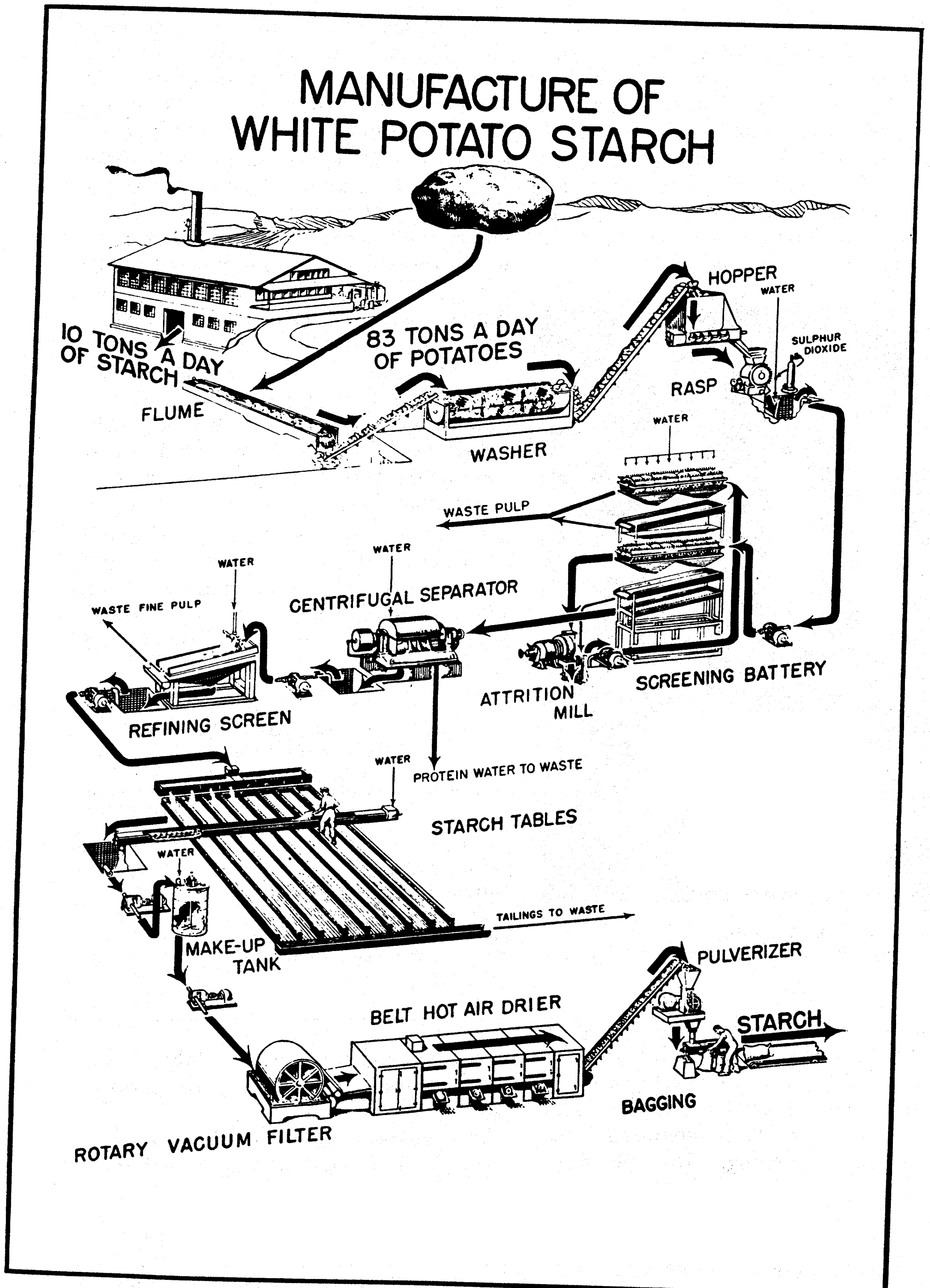

FIG. 2. Flow diagram for manufacture of white potato starch as carried out in a modern factory in Maine.

methods and equipment used in other modern factories differ in some ways from those given here, but the general steps are similar.

Starch plants in Maine have storage facilities for handling 10,000–12,000 bushels of potatoes at the factory. The potatoes are removed from the storage bin by way of a flume which carries them to a conveyor and at the same time removes stones and much dirt. The conveyor lifts the potatoes up to the washer, where the remaining dirt is removed. The potatoes are then elevated to a hopper from which they fall to a screw conveyor that regulates the raw material flow to the rasp. The rasp reduces the potatoes to a slurry. The slurry is diluted with water to facilitate subsequent screening. Sulfur dioxide is added at this stage to inhibit the action of oxidative enzymes and thereby aid in producing a white starch. The dilute slurry is pumped to a battery of screens on which most of the cellulosic material is retained while the starch passes through.

The screening battery consists of screens and sieves mounted vertically in the following order: Lower shaker screen (80-mesh), lower rotary brush sieve (perforated with 0.03″ diameter holes), upper shaker screen (100-mesh), and upper rotary brush sieve (perforated with 0.02″ diameter holes). In the screening operation the starch is first pumped onto the bottom sieve. Here the starch and water pass through and the pulp is discharged off the end of the sieve. The pulp is diluted with water and drops into an attrition mill for a second grinding to release a further quantity of starch. The starch suspension, with the fine pulp that passed through the lower sieve, falls onto the lower shaker screen. The starch granules pass through and most of the fine pulp is discharged from the end of the screen later to be mixed with the reground pulp from the attrition mill. The combined pulp is then pumped to the upper sieve where it is washed with a water spray. The fine pulp and starch pass through this sieve and drop onto the upper shaker screen. The starch suspension passes on through to the lower shaker screen. The fine pulp from the upper shaker screen and coarse pulp from the upper sieve are joined to constitute what is called the pomace or waste pulp which is discharged to the sewer.

The starch suspension from the screening battery is then pumped to a centrifugal separator where the "protein water", *i.e.*, wash water containing the soluble materials, is removed. The starch from the continuous centrifuge is diluted with water and pumped to a refining screen (120-mesh) which removes additional fine pulp. The starch suspension is then pumped to tables where the starch settles and the remaining traces of fiber and soluble substances flow off at the end.

The starch cake scraped from the tables is then diluted to the proper density for pumping to the continuous rotary vacuum filter. After dewatering to about 40 percent moisture, the cake is dried in a continuous belt drier to about 17 percent moisture (3).

The finished starch has approximately the following percentage composition on the dry basis: starch, 98 to 98.5; ash, 0.3; cold-water-soluble compounds, 0.1. It contains about 0.5 percent fibrous material and traces of nitrogen compounds and sugars.

Utilization

Maine potato starch is used in its various outlets in approximately the following proportions, expressed in percentages[4]: textiles, 42; paper, 28; food uses, including thickeners and confections, 14; adhesives, 10; miscellaneous, 6.

[4] Obtained from M. C. Bartlett, Maine Institute of Potato Starch Manufacturers, by correspondence, November 13, 1950.

During the period prior to World War II domestic potato starch nearly always sold at a higher price than cornstarch. Imported potato starch at times sold at about twice the price of domestic cornstarch (4). For many years this price relationship confined the use of potato starch to special applications in which its unique properties make it preferable. 1937, however, was about 2.4 billion pounds, including 1.5 billion pounds used for glucose sirup and sugar manufacture. The remaining 0.9 billion pounds was used for export and manufacture of dextrins and modified starches.) The demand for domestic potato starch in 1937, however, was sufficient to result in the sale of only 17 million pounds of starch.

FIG. 3. A potato field in flower in Aroostook County, Maine. (*Courtesy Rohm and Haas Company*).

The availability of imported tapioca starch at a price generally competitive with corn starch was another factor limiting the demand for potato starch during the decade preceding World War II. Tapioca imports reached the high level of 433 million pounds in 1937, which can be compared with 685 million pounds of cornstarch sold that year in the United States for use as starch (4). (The total cornstarch production in

Most of the tapioca starch used in the United States during the 1930's was imported from The Netherlands Indies. In fact, a high percentage of the total tapioca starch exported from that country at the time was shipped to the United States. Outbreak of the war in the Pacific late in 1941 cut off imports from this source. Fortunately our domestic white potato starch industry began expanding and modernizing in 1938 and was thus able to meet increased demand for its product. As a result potato starch production was increased to furnish a sufficient supply of this starch for the most essential uses and to replace in part the unavailable imported root and tuber starches.

Since the close of World War II, some tapioca starch has been imported from Brazil and Santo Domingo, but this starch has not resumed anything like its former position.

For the past three years potato starch and cornstarch have sold at five and one-half to seven cents a pound delivered to eastern cities; at times potato starch has even been cheaper. This favorable price situation, coupled with the industry's successful effort to assure a continuous supply of high grade product, has increased the general use of potato starch.

Textiles. More potato starch is used in the sizing of cotton, worsted and spun rayon warps in the textile industry than in any other single application. In warp sizing, parallel threads that run lengthwise in the loom dip into a bath of hot starch paste formulation; the sized thread passes over heated drums to effect drying after leaving the bath. The function of warp sizing is to bind tightly the loose fibers to the surface of the thread and thereby strengthen and protect the warp from abrasion during weaving. " High count " warps, containing many individual fibers spun together, are difficult to size because of small interstitial space betwen the fibers. Potato starch is preferred to cereal starches in warp sizing because its paste penetrates farther before gelling. Deeper penetration of the starch results in formation of a film that adheres well to the warp and consequently gives it more strength and resistance to abrasion. It is well known that potato starch films have a high degree of toughness and flexibility relative to other starches. This permits potato starch sized warps to be woven at lower humidity than those sized with cornstarch.

The smooth clear pastes obtained with potato starch also have other advantages in warp sizing. Cereal starch pastes frequently contain large aggregates of gelled material which stick to the warp and subsequently get caught in the loom to cause thread breakage. Potato starch sized warps not only have a smoother finish but also are easier to de-size after the size has served its purpose. The lesser tendency of potato starch pastes, in comparison to cereal starch pastes, to " set back " or retrograde to a gel is of advantage following shutdowns. It is also claimed that less tallow is required in potato starch sizes to minimize sticking of warp to drying drums than with other common starches. Potato starch is said to be superior for sizing warps that have been previously dyed in that it gives a brighter color.

The finishing of cotton sewing thread is similar to warp sizing. The thread is immersed in a finishing bath and then passed over brushes to provide a smooth finish. Many manufacturers of cotton thread, like textile manufacturers in their warp sizing, use potato starch exclusively.

Potato starch is not outstanding in its ability to bring out color intensity of vat dyes when used as a thickener for textile printing pastes, but it possesses superior properties as a finishing agent. Cloth finished with potato starch has a better " feel " and smoother surface than obtained with cereal starches.

Paper. Although it has long been known that potato starch has valuable properties for many applications in paper manufacture, its use previously was not common, even in mills in starch-producing areas. During the past few years, however, expanded use in the paper industry has been the leading potato starch development.

Starch is used for four purposes in paper manufacture: (*a*) beater sizing in which the cellulosic fibers are cemented together preparatory to sheet formation; (*b*) tub sizing, in which the preformed sheet is passed through a dilute size solution; (*c*) calender sizing, in which a smooth finish is imparted; and (*d*) surface coating, which is an optional step in finishing high-grade papers. Starches and dextrines are also used in combining and sealing paperboard in the fabrication of folding, corrugated and laminated solid-fiber boxes.

FIG. 4. Harvesting potatoes in Aroostook County, Maine. (*Courtesy Rohm and Haas Company*).

Cold-water-soluble potato starch is outstanding in its performance in beater sizing. This modification is produced by cooking a suspension of the starch, drying the paste on drum driers, and grinding the flakes to a powder. This type of soluble potato starch was first manufactured in Holland and has been produced for years in this country to supply a steady market. Soluble potato starch or " gum " is preferred to the corresponding products from other starches in beater sizing because its paste possesses great stringiness and cohesive strength. Furthermore, these properties are said to be affected relatively little on addition of alum. Alum is regularly used in paper manufacture, and its acidic character is detrimental to the properties of most starch pastes.

Food. Much of the potato starch utilized in the food industry is used in bakers' specialty items, such as Swedish and German style breads, in crackers and in matzoth. It is also used as a thickener in soups and in gravies. Potato starch has been pelleted successfully to make puddings similar to those ordinarily made from tapioca starch. Although potato starch puddings were rather well received during the last war when tapioca was unobtainable, the food trade seems to prefer tapioca puddings. As a result the use of potato starch in puddings is at present rather limited.

Starch is used in the confectionery industry for the following purposes: (*a*) as a medium for molding cast candies such as jelly beans, " orange slices " and gum drops; (*b*) as a bodying agent and to impart smoothness and stability to caramels and marshmallow; (*c*) as a thickening agent in synthetic jellies; (*d*) as a dusting agent, perhaps mixed with powdered sugar, for candy gums, chewing gum, etc. Thin-boiling starch (treated to reduce its paste viscosity) rather than thick-boiling starch (unmodified) is ordinarily used as an ingredient in candy manufacture. Starch constitutes 10–12 percent of the total weight of dry ingredients in candy gums. Glucose sirup produced by the hydrolysis of starch is widely used in candies, beverages, chewing gum, ice cream and confections in general. Very little potato glucose sirup is being produced at present; during World War II, however, when corn, beet and cane sirups were under allocation, several plants made potato sirup.

FIG. 5. Harvesting potatoes in Aroostook County, Maine. (*Courtesy Rohm and Haas Company*).

Adhesives. In producing adhesives it is generally advantageous to modify starch by chemical or physical treatment to reduce its paste viscosity, thereby permitting use of higher solids concentration, and to develop so-called tackiness. Although some potato starch is modified for use in adhesives by treatment with an acid to produce "thin-boiling" starch or with alkaline hypochlorite to produce "oxidized" starch, most of it is used in the dextrinized form for this purpose. Dextrins are produced by roasting starch in the presence of an acid catalyst. It is a well known fact that films of dextrins made from root and tuber starches, such as tapioca, sweet potato and potato, have greater flexibility and resistance to checking than dextrins of cereal starches. Potato dextrins are used in many applications in which their specific properties make them desirable; for example, as a binder in sand paper, abrasive cloth, bookbinding and rug sizing, each of which requires a dextrin of high paste tackiness and of flexible residual film. Potato dextrin films are also outstanding for their ease in remoistening; this property is desired in mucilages used for gumming stamps, labels, envelopes, paper tape, etc.

Miscellaneous Uses. There are a number of miscellaneous uses of starch that cannot be classified under the general categories discussed above. Examples of these uses include utilization of starch as (*a*) hygroscopic addition agent in baking powder; (*b*) fermentation raw material; (*c*) binder for tablets; (*d*) binder and extender for sausages; (*e*) builder for soap; (*f*) separator in dry cell batteries; (*g*) raw material for nitrostarch manufacture; (*h*) consistency stabilizer for oil well drilling "muds"; (*i*) attractant in insecticidal mixtures; (*j*) boiler feed water treating agent; and (*k*) clarifying agent for waters used in mining operations. The miscellaneous uses of potato starch probably include some of these listed. Manufacturers and distributors of potato starch, for business reasons, hold as confidential information concerning some of the lesser uses of their product.

Outlook for Potato Starch

The potato starch industry has made great strides during the past 10–15 years in providing its consumers with more and higher quality domestic starch than heretofore available. The demand constantly exists for large quantities of potato starch. It is impossible to predict exactly how fluctuations in the size of future potato crops may affect starch production. Although smaller potato crops may be in store than the large crops occurring during the last decade, many leaders in the potato industry believe that close grading of tablestock potatoes in the future will assure an adequate supply of culls for starch manufacture.

The potato starch industry reached a high level of production in 1950–51. Since this starch is advantageous for many applications in which it was not previously used, however, further extension of its uses could possibly take place. Greater use in the paper industry in New England and in the Northwest offers perhaps the best opportunity for expansion. Continued growth of the potato starch industry depends primarily upon whether the manufacturers can continue to match the competition of other starches in quality, supply and price.

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